第1章

SCIENCE POLICY IN THE U.S

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Profile:
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Abstract:

The contributions of scientific and engineering research to understanding the natural world around us, and to their practical applications in the betterment of society and in providing the conveniences of everyday life are diverse and far-reaching. The scientific enterprise is inclusive, drawing together researchers, educators and policy makers in devising and managing a "science community" that is responsive to societal needs. Science policy decisions influence many sectors, including the economy, safety and security, health, and the environment. Support for science occurs through investments in people, ideas and tools. The budgeting process that provides for these investments is lengthy and complex, reflects many interests, and is constrained by budgetary reality. National science policy emerges from coordinated government-wide organizational planning and leadership vision of future needs and challenges. The strategic plan of the U.S. National Science Foundation is discussed as an example of funding agency management and portfolio development.

Outline:

I. Introduction
II. History of American Science Policy
III. Research and Development (R&D) Investment

I. Introduction

Understanding how science policy is formed and implemented is an important part of scientific literacy, and it is pleasing to see this topic included in the Shonan Lecture series. The subject of this lecture is American science policy. I will begin the presentation with a brief history of science policy in the United States beginning at an early date in American history and progressing to the present time, with remarks on important events in the evolution of American science policy. Since science policy guides investments in the scientific enterprise and ultimately leads to practical decisions regarding the allocations of funds to individual scientific programs, United States domestic and international spending on research and development (R&D) will be reviewed. As you will come to know, expenditures on R&D go towards basic research, technology development and commercial application, with non-uniform involvement of investors and performers in these sectors. Next, the advisory and consultative steps in determining and establishing American science policy will be discussed, followed by a review of the budget process in the United States and how science policy is translated into funding support in particular areas. Finally, accountability for responsible investment in science and technology (S&T) has increased in recent times. In this regard, the importance of outcome reporting and the mechanisms to achieve this will be introduced. The role of the funding agency, using the U.S. National Science Foundation as an example, in contributing to the development of science policy and in executing science policy through the management of scientific and engineering research and education activities will be woven into this lecture.

Not only does national science policy point the way for investments in S&T that will advance the frontiers of knowledge and benefit society through improvements in safety, health, prosperity and general well-being ("policy for science"), but also the advancements in basic knowledge and technology resulting from R&D activity influence policy decisions regarding science and other areas ("science for policy").

We might begin to address the topic by asking why should a nation such as the United States, or any nation, have a science policy. Science policy guides a country in meeting its responsibility to support the scientific enterprise in a manner that serves the greater good of society, and a clearly defined policy for investment is the first step in fulfilling those responsibilities. The four responsibilities for U.S. federal science enterprise are (National Science and Technology Council, 2004):

- ***To promote discovery and sustain the excellence of the American research enterprise.*** Simply put, to be competitive on a global scale and to achieve desired advances in science and technology, overall funding support across a spectrum of fields is essential.

- ***To respond to national challenges with timely and innovative approaches.*** It is not enough simply to provide general funding. In fact, timing is an important part of strategic investment. We know, for example, that at this moment some specific areas of academic or applied research are especially relevant to our needs, and so we respond aggressively and with focus. Examples of contemporary challenges include developing treatments and management strategies for emerging infectious diseases, and engineering safer building capable of withstanding major seismic events.

- ***To invest in and accelerate the transformation of science into national benefits.*** The translation of basic research findings into technologies, and from there into new and improved goods and services such as telecommunications, health care, security, *etc.*, requires integration across sectors (basic research, technology development and commercialization). When one of my colleagues hears about a basic scientific discovery, he jokingly asks, "Will this new finding improve my television reception?" Seriously, however, he wants to know what will be the practical application of the discovery, and will our quality of life be improved as a result.

- ***To achieve excellence in science and technology education and workforce development.*** It is critically important that we take a long-term view when considering investments in science. A globally competent workforce in the future depends on investments in science and engineering education now. Without that support for education and training, the national workforce cannot keep pace with that in the rest of the world.

II. History of American Science Policy

The year 1945, although it marks neither the beginning nor the end chronologically, is a good place to begin a historical discussion since it marks the beginning of modern science policy. In 1944, as the Second World War ended, then-President of the United States Franklin D. Roosevelt requested from his advisor Vannevar Bush a report on how the federal government might best promote scientific progress in the post-war period. At that time, Bush was head of the Office of Scientific Research and Development, and he himself may have even initiated the idea of the report (Blanpied, 1998). The preparation of the report required a few months, and in 1945 it was delivered by Bush to the new President Harry S Truman. The report was significant for several reasons; it carried recommendations on the role of the government in supporting scientific and engineering research, and it led eventually to the establishment of the U.S. National Science Foundation (NSF). Until this time, there was not any governmental organization in the United States to fund or to manage basic academic research in science. Certainly the government supported research activities, but typically these were specific projects with very practical applications. Using a few quotations from the report (Bush, 1945), a clear sense of the nation's situation and experience emerges, as does a statement on the vital interest to the government of continued scientific progress:

> "Progress in the war against disease depends upon a flow of new scientific knowledge. New products, new industries, and more jobs require continuous additions to knowledge of the laws of nature, and application of that knowledge to practical purposes." (p. 5)
>
> "This essential, new knowledge can be obtained only through basic scientific research." (p. 5)
>
> "The responsibility for basic research in medicine and the underlying sciences, so essential to progress in the war against disease, falls primarily upon the medical schools and universities." (p. 5)
>
> "The responsibility for the creation of new scientific knowledge—and for most of its application—rests on that small body of men and women who understand the fundamental laws of nature and are skilled in the techniques of scientific research." (p. 7)

> "Moreover, since health, well-being, and security are proper concerns of Government, scientific progress is, and must be, of vital interest to the Government." (p. 11)

Until the mid-twentieth century in the United States, the universities and colleges played a relatively minor role in the national science and engineering enterprise. University faculty, of course, comprised a large population of academic researchers, and the "research active" scientists and engineers within this group might typically have received funds from private foundations to support their work. In the first half of the century, the amount of funding derived from foundations for basic research was typically modest, but applied research during the war years brought larger investments from government to projects in the academic sector (the development of radar being one example), both in the U.S and abroad. This was a turning point in recognizing the potentially much larger role that universities and medical schools could play in the scientific enterprise. The report acknowledged the skills of that group and formed the basis for expanding its role in the national R&D effort and for considerations related to "workforce development" as a part of science policy.

Early History of American Science. Stepping back in time, we see that the pursuit of scientific exploration and experimentation was an amateur undertaking. This portrayal is not unique to the United States, but is appropriate to other countries, too. Many scientific discoveries came from the work of individuals who were characteristically very wealthy gentlemen who had occupations in service to government or other institutions or, perhaps, they were so-called "gentlemen of leisure," belonging to very wealthy families. These "gentlemen" conducted science as a hobby, driven by personal interest and curiosity. And they conducted their experiments independently, with their results reported to learned societies of like-minded gentlemen.

An example of one such gentleman scientist is Benjamin Franklin, who in the mid-1700's conducted his famous experiments with a kite. Using the very simple equipment of a kite on a string, a key and a jar, Franklin made some very interesting discoveries about static electricity. He reported his findings at meetings of similarly minded men. In fact, in 1743, Franklin founded the American Philosophical Society, which is the oldest scientific society in the U.S. This was the state of American science at the time of the country's birth. After the United States claimed its independence in 1776 and established a government through its

Constitution in 1789, there was no real science policy, although the constitution gave the United States government the authority to grant patents and copyrights. That is, the government afforded protection for some inventions and technologies that might follow from basic discoveries. It also gave the government the authority to control weights and measures (that is, to implement standardization of commercially important units) in the U.S. At this same time, international conventions were establishing standard units of length (the meter) and mass (the kilogram) that were important to scientists. And finally, there was authorization for the government to conduct a 10-year national census to obtain a demographic measure of what is happening in the country. Information about the population can used in assessing the needs of the country, and this is one factor in designing policy. The Constitution gave educational authority to the states rather than to the federal government (that is, there is not a national education system in the U.S.). As a result, this affects the role and impact of the government in influencing the training scientists and engineers.

The beginning of a national scientific infrastructure. In the early-19th century, the federal government took on some responsibilities that might be viewed as applied science. This can be illustrated with two examples. The first is the National Geodetic Survey (originally established as the Survey of the Coast in 1807 by President Thomas Jefferson, and now part of the National Oceanic and Atmospheric Administration, NOAA), which was charged with charting the coastlines of the United States and making maps for sailors. This required the development and application of technologies and techniques for geographical surveying. The second is the United States Naval Observatory, which was originally founded in 1830 as the Depot of Charts and Instruments, one of the country's oldest scientific agencies. The Naval Observatory in Washington, D.C. provided maps and information about the United States coast and surrounding waters, and it maintained precision timepieces. The Observatory utilized an ingenious "ball lowering" technique to signal the exact time of twelve o'clock noon each day to ships in the harbor. Ships in visible range of the Observatory used this precisely timed event to calibrate their nautical clocks that were essential for accurate navigation at sea. Increasingly more accurate maps and engineering advancements in timekeeping followed under government guidance and support.

In the mid-19th century, at the time of the American Civil War (1861-1865), the government enacted several laws that supported educational training in various ways. (Recall that the U.S. government had established a policy not to become involved in education and training, reserving this to the individual states of the Union.) The Morrill Land Grant Acts of 1862 and 1890 promoted the establishment of universities. Under the Land Grant Acts, the federal government, which owned large areas of land, gave parcels of that land to the states. The states were free to sell that land to farmers and ranchers, and to others who desired to own such property. The money obtained by the states from the sale of that land was to be used to establish universities. In this fashion, the federal government promoted the formation in the United States of what are called "land grant universities." At land grant universities, the major fields of study are typically agriculture, manufacturing technology, and so forth. These are fields of practical study that would be useful to an expanding and growing country, such as the United States at that time, by promoting training and employment in technical arts, for example. In the same year (1862; during the administration of President Abraham Lincoln), the Department of Agriculture was established. Importantly, farmers comprised almost one-half of America's population at the time. With agriculture being a major economic sector and providing important employment for many people, the Department of Agriculture had very practical objectives; namely, it provided to farmers good seeds and information that were needed to grow crops efficiently. In one regard, the Department supported applied scientific research through early work on plant breeding, for example, to produce new and better seeds to improve agricultural production. To this day, the Department of Agriculture plays an important role in research and science policy relating to the nation's food production and to the safety of food. The National Academy of Sciences (NAS), established in 1863, has a membership elected by the academic community and it provides scientific advice to departments of the government on request, and to others. It's interesting to note that, when it was established, the prestigious National Academy of Sciences received money only for its actual expenses, affording it a large measure of independence and impartiality that insures honest, unbiased information in its reports and advice.

Later, acts similar to the Morrill Land Grant Acts reinforced the federal government's commitment to research and education; the Hatch Act (1887) established agricultural experiment stations at land grant universities, and the Smith-Lever Act (1914) established "Cooperative Extensions" as partnerships between Department of Agriculture and land grant universities, and local governments or organized groups. With the assistance of federal funding, these agricultural experiment stations and cooperative extensions conduct agricultural research and communicate the resulting practical information to farmers. Most recently, in 1966, Sea Grant Colleges were established with much the same focus as land grant colleges, *i.e.*, practical research and training. But in this case, the investment and effort are directed at the sea, including investigations into areas including fisheries, aquaculture, the marine environment, and climate change. Like the land grand system, this is a way for the federal government to be engaged with universities in the promotion of scientific research. The National Oceanographic and Atmospheric Administration in the Department of Commerce manages the Sea Grant Program.

Following the American Civil War, the nation entered a very active and extended period of industrialization and economic growth. In 1916, the National Academy of Sciences established the National Research Council (NRC). The purpose of the NRC was to associate the broad community of science and technology with the Academy's purposes. To operate effectively as a non-governmental advisory body in science, the National Academies (including the National Academy of Engineering since 1964, and the Institute of Medicine since 1970, in addition to the NAS) relies upon the expertise of scientists, engineers and medical researchers; the NRC provides a mechanism for that broad access. At the same time, in 1915, President Woodrow Wilson formed the National Advisory Committee for Aeronautics. This agency had the very specific mission of providing advice on aviation related issues. The idea for the National Advisory Committee for Aeronautics (NACA) arose when the United States looked at the state of aviation in Europe and realized that Europe was far ahead of the United States. The valuable strategic role of airplanes and of airplane technologies in the First World War highlighted the disparity even more. The United States government response was the establishment of NACA, which not only provided advice on aeronautical development in the U.S. (a science policy contribution) but also operated research facilities. Later, NACA became part of the National Aeronautics and Space Administration (NASA).

Science and technology research and development sectors. At this time in the early 20th century, three different sectors in science research and development are recognizable, generally (but not always), in the following way:

- ***Industrial sector***: applied research and development, application of practical technologies to commercial devices and products, generally self-funded;

- ***Government sector***: sponsorship and conduct of research and development in defined areas, and on specific projects; and
- ***Academic sector***: basic research conducted broadly to build and to expand the general knowledge base, generally supported by private foundations and internally.

Until the early-20th century, these sectors operated nearly independently and without great cooperation, each addressing their individual objectives.

Emergence of modern-day science policy. It can be argued that modern American science policy, as we know it today, takes its origin in 1940 and the opening of the Second World War. The War increased the national focus on research and development capability, and on the mobilization of science and technology resources. In response to that call, scientists and engineers were engaged for military and defense research. Some of this contracted research was hosted in university and company laboratories, and resulted in the development of equipment such as radar and jet propulsion engines. This research mode is significant since it represents an intersection of the industrial, government and academic research and development sectors. In 1944, as the end of War approached, President Roosevelt turned to his science advisor, Vannevar Bush, asking what lessons might be learned about promoting science and technology research and development from experiences during the wartime years. Specifically, the President asked Bush about what role the government could take in supporting peacetime domestic scientific research. The resulting report, submitted in 1945 to President Truman, was entitled, *Science—the Endless Frontier*. The report makes two major recommendations. The first recommendation was not to interfere with industrial research. Industrial research laboratories were already functioning quite well pursuing applied research and developing products for the marketplace. The second recommendation was that the government should support non-defense, basic research activities to promote scientist and engineer training for employment in industry, government and academia and to maintain the flow of research findings for practical application. Bush recognized that if industry is to continue the development of new products for the improvement of life (through pharmaceuticals and disease treatments, for example), it must steadily be fueled with new basic knowledge. The government's role should be the promotion of the underlying basic research and the training of scientists, and the universities should be the place where this occurs. In Bush's vision of the future, the universities would take a more central position in research.

It can be argued that modern science policy has emerged over the last sixty years, since the time of the Bush Report. Adoption of the report's second recommendation (that the universities take a central role in basic research and that the government support that activity) required a funding mechanism. The question of how funds would be provided to the university performers of research was answered with the proposal that there should be a national research foundation to administer such a sponsoring program and to deliver the funds. It was five years before a research foundation emerged as the National Science Foundation in 1950. Most of the agencies and departments with roles in conducting or supporting scientific research had been established by this time: the Department of Agriculture (which is the oldest), the National Advisory Committee for Aeronautics (which became part of NASA in 1958), the National Science Foundation, the Department of Defense (established in 1949), the Atomic Energy Commission (established in 1946, and which became part of the Department of Energy in 1974), and the Department of Health, Education and Welfare (established in 1953, and which became the Department of Health and Human Services in 1980). Looking at science policy in the United States, basic themes can be related to each of these organizations: food and food safety, transportation, basic science research, safety and security, energy, and health and well being. The year 1957 was an important one in the history of American science policy. The launch of the Sputnik satellite by the former Soviet Union marked the start of the "space race." Just as the National Advisory Committee for Aeronautics was formed in response to the advanced nature of aviation technology in Europe, the formation of NASA in the year following the Sputnik launch responded to a perceived need to advance the American position in space exploration. In an even larger perspective, the last half-century has been a period of extraordinary growth of the American science enterprise, with strong investments in science and technology, including education and training.

III. Research and Development (R&D) Investment

Science policy includes, and is often discussed in the context of, the decisions regarding financial investments in science and technology R&D. Some background information on R&D investments will set the stage. In 2002, the total amount of spending on research and development in the United States was US$276 billion (National Science Board, *Science and Engineering Indicators 2004*, p. 4-10, Table 4-1). Expenditures by the industrial sector are far greater than those by either the federal government or others (includes universities and colleges, non-profit institutions, state and local governments, *etc.*; Figure 1).

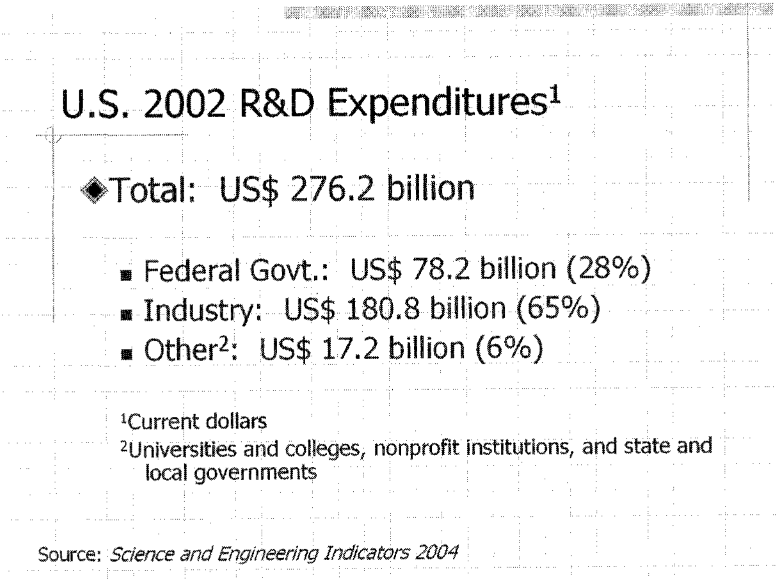


Figure 1. U.S. R&D expenditures in Fiscal Year 2002

The total R&D spending in the U.S. represented 2.82% of the Gross Domestic Product in FY 2000-2001, a value among the highest when compared with that for other industrialized, developed countries; for Japan, the ratio was even higher, at 2.98% in JFY 2000 (Figure 2; National Science Board, *Science and Engineering Indicators 2004*, p. 4-51, Table 4-17).

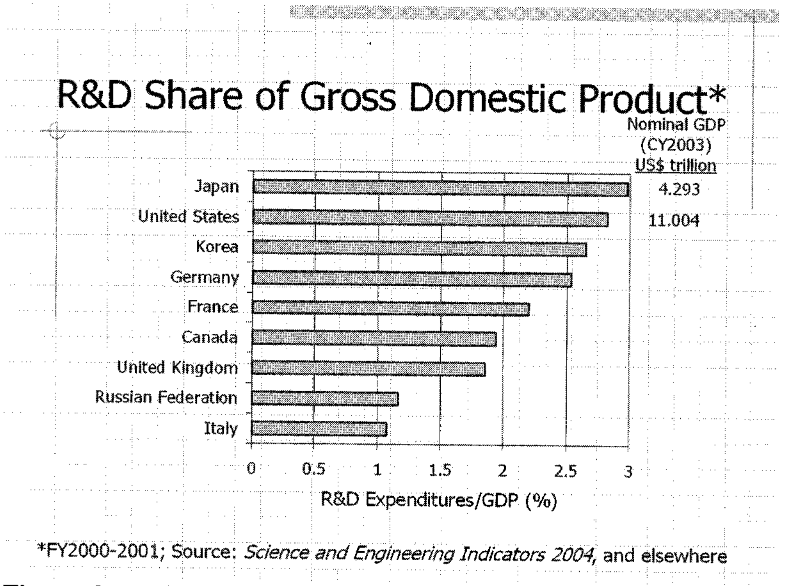


Figure 2. R&D investment as percentage share of Gross Domestic Product (GDP)

It is interesting to note that there is no strict quantitative equivalence between the sources and the performers of R&D. For many countries, including both the U.S. and Japan, industry is the largest source (Figure 3) of R&D expenditures, accounting for roughly two-thirds of the total R&D. Government sources (about one-quarter of the total expenditures) and other sources (less than a tenth of the total) spend considerably less.

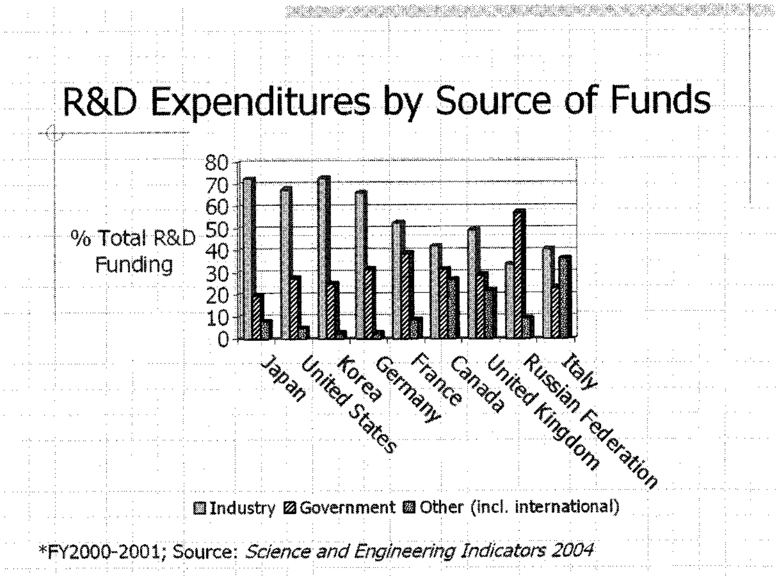


Figure 3. R&D expenditures by source of funds, as percentage of total

When R&D expenditures are examined according to performer, a different pattern emerges. Whereas industry is again the largest performer, relative expenditures in performance by the government represent a smaller fraction of the total with the balance attributed to others (Figure 4).

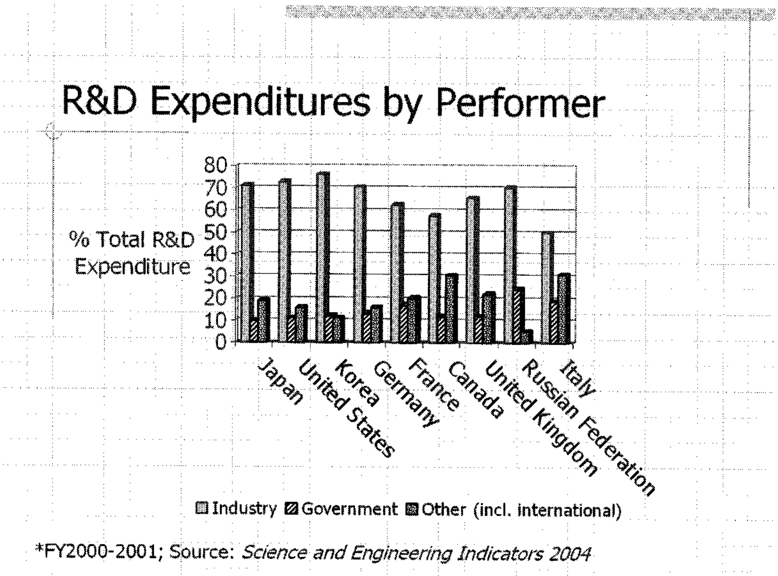


Figure 4: R&D expenditures by performer, as percentage of total

Universities represent a substantial part of the "other" category, and they conduct much of their research with money provided by the federal government. The government does conduct some research in its own laboratories using its own employees, but a substantial part of federally funded research is conducted by faculty in universities.

Three R&D sectors can be identified and the relationships among them (as knowledge and technology flow) characterized (Figure 5). *Basic research* produces fundamental knowledge through discovery and develops useful insights. *Applied research* produces new enabling technologies from fundamental knowledge. *Development* builds commercial applications from technologies in response to societal and market needs. Certainly, marketplace and other conditions are drivers of R&D activity.

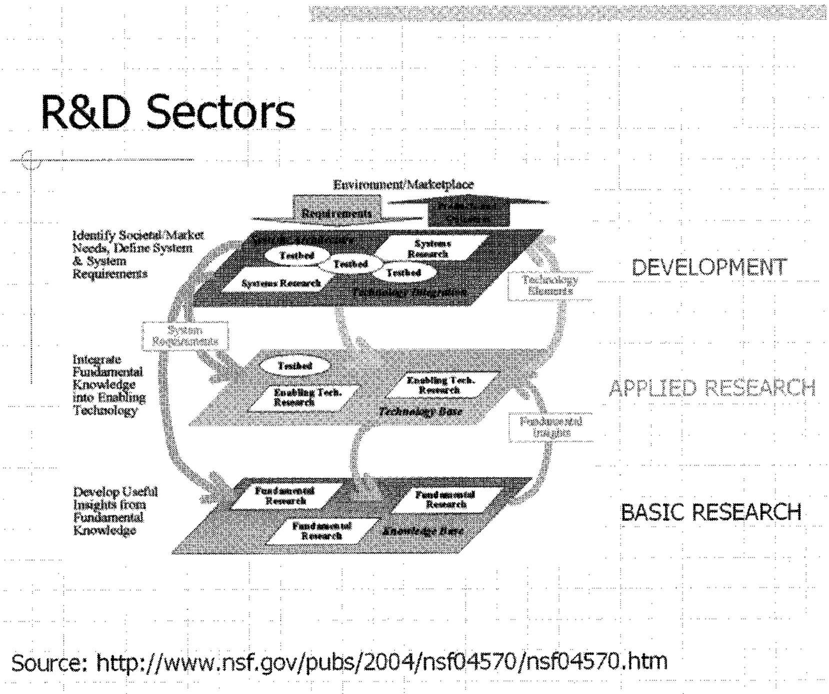


Figure 5. Relationships among R&D Sectors

Not unexpectedly, industry, government and other participants in the R&D enterprise contribute to funding and performance at different levels, as illustrated graphically in Figures 6 and 7.

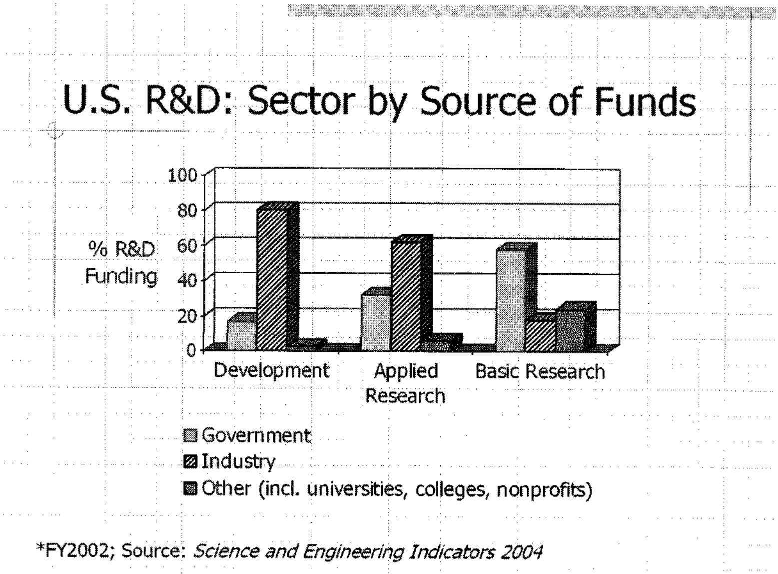


Figure 6. U.S. R&D: sector expenditures by source of funds

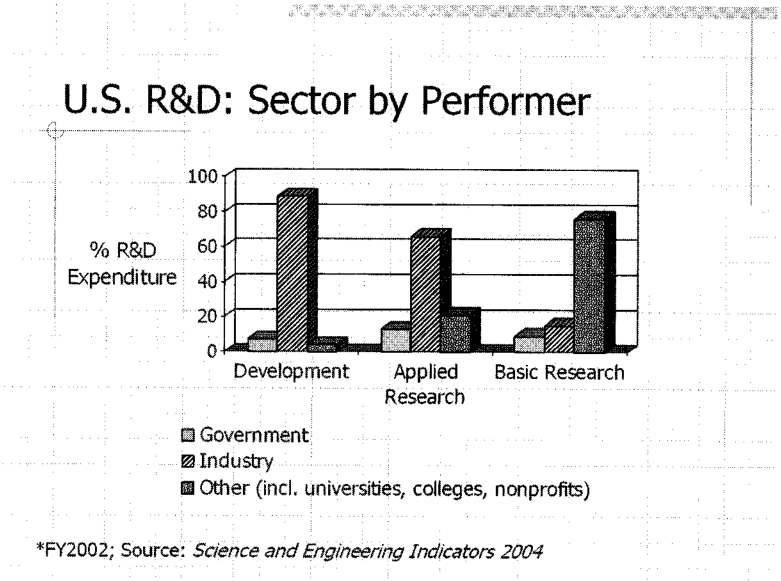


Figure 7. U.S. R&D: sector expenditures by performer

Industry, the largest participant in R&D activities, contributes most greatly to the development and applied research sectors, *i.e.*, those sectors closest to the marketplace and commercial activities. Industry investments in technology application and commercialization are returned through product sales in a relatively short time compared with investments in basic discoveries, which may achieve commercial application only after many years, if ever. The government contributes substantially to all sectors through its funding activities (with greater support to basic and applied research relative to development), but is a minor performer in all of the sectors. The contributions of universities and colleges and nonprofit research institutions to basic research performance are striking, and highlight the importance of this group to the advancement of basic knowledge. The data also point to the dependence of academic research activity on extramural funds provided largely by the government. For the R&D cycle to operate effectively, *i.e.*, for fundamental knowledge to appear ultimately in technologies and products useful to society, knowledge and technologies (as intellectual properties) must be transferred between and among sectors. The handling of intellectual property rights in this context is complicated and challenging, and for information the reader is referred elsewhere (Kneller, 2003).

Overall, U.S. government agencies devote slightly more than one-quarter of their total R&D budget to basic research, with the balance appearing as investments in application and development (Figure 8).

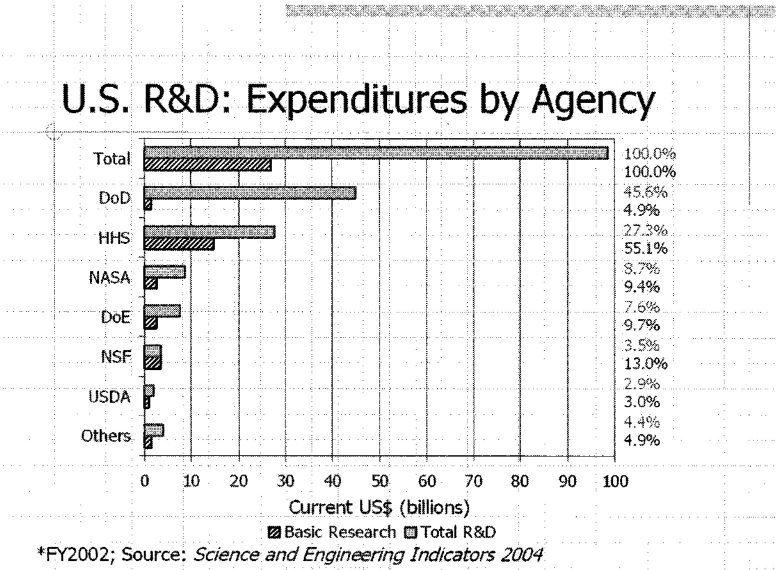


Figure 8. U.S. R&D: expenditures by agency

As indicated in the figure, the agencies differ with regard to the fraction of their total R&D budget that goes towards basic research, with the National Science Foundation and the Department of Health and Human Services (HHS) leading in that measure, and also in absolute dollar amount. For a comparison and an appreciation of the real value of industrial investment, it is interesting to note that ten American corporations individually had total R&D investments in FY2001 exceeding US$3 billion (National Science Board, *Science and Engineering Indicators 2004*, p. 4-22, Table 4-7).

IV. How Science Policy is Determined

The determination of national science policy depends on the advice and recommendations of individuals and groups representing stakeholder communities, including policy advisors in the government, independent advisory organizations such as the National Academies and the National Research Council, Congressional budget legislators, and the science funding agencies through their budget requests. The contribution of each group to the policy dialogue reflects a view of national and societal needs. Economy, safety and security, health, and the environment are all important factors that must be weighed in the process. And, in the end, science policy is built on a vision of present and future needs and opportunities, and is ultimately reflected in the government's science and technology investments through the budget process.

Organizations involved in designing and determining national science policy include:

- ***Office of Science and Technology Policy (OSTP).*** OSTP is an office of the Executive Branch of the United States government, and is directly responsible to the President, advising the President and others in the Executive Office of the White House on matters of domestic and international science and technology. It implements sound science and technology policy and budgets, and it determines national priorities with input from advisory groups in the government, academic and private sectors. On a global scale, science and technology agreements with other countries guide scientific direction and cooperation on a larger scale. Headed by a Director, two Associate Directors manage a science portfolio (including environment, life science, physical science and engineering, and social, behavioral and education sciences fields) and a technology portfolio (including technology, telecommunications and information technology, and space and aeronautics), respectively. Information on national S&T policy and priorities is available at the OSTP Web site (http://www.ostp.gov).
- ***President's Council of Advisors on Science and Technology (PCAST).*** PCAST provides advice from the private sector and academic community on technology, scientific research priorities, and math and science education. Within PCAST, academic scientists and engineers can talk with industry counterparts to exchange ideas. PCAST recommendations are transmitted to OSTP; reports are available at the PCST Web site (http://www.ostp.gov/pcast/pcast.html).
- ***National Science and Technology Council (NSTC).*** NSTC is a Cabinet-level council including in its membership the President, Vice President, Director of OSTP, Cabinet secretaries and agency heads with significant S&T responsibilities. NSTC establishes clear national goals for government S&T investment. Reports are available at the NSTC Web site (http://www.ostp.gov/nstc/html/nstc.html).

- ***The National Academies (National Academy of Sciences, NAS; National Academy of Engineering, NAE; and Institute of Medicine, IOM).*** The National Academies provide independent, non-governmental advice to the national science policy process. Membership in The National Academies is through election by the academic community; currently there are nearly 6,000 members. A visit to The National Academies Web site (http://www.nas.edu) will provide the reader with an impressive look at the wide variety of science and engineering topics covered by this organization.

- ***National Science Board (NSB).*** The NSB is the governing body for NSF. The NSB serves as an independent national science policy body that provides advice to the President and Congress on policy issues in science and engineering. There are 24 members that are appointed by the President and confirmed by Congress. In addition to its advisory role to government, the NSB also oversees and guides activities of, and establishes priorities for, the National Science Foundation, an independent science funding agency of the Executive Branch of the government. The NSB prepares the biennial *Science and Engineering Indicators* quantitative reports on U.S. science, engineering and technology for use by policymakers. These reports, as well as others, are available at the NSB Web site (http://www.nsf.gov/nsb/).

Ultimately, after consideration of input from this broad array of advisory groups, a national science policy, coordinated by the government, emerges that identifies priority areas for S&T investment. Currently (July 2004), national S&T priorities, with examples, are (National Science and Technology Council. *Science for the 21st Century*, pp. 15-19):

- ***Homeland and National Security***: developing vaccines, biometrics and sensor technologies, and mapping pathogen genomes; anti-terrorism R&D; university-based Homeland Security Centers

- ***Health***: SARS and West Nile virus defense and treatment

- ***Energy***: Hydrogen Fuel Initiative; International Thermonuclear Experimental Reactor

- ***Environment***: Climate Change Research Initiative; particulate matter effects on cardiovascular disease

V. The Budget Process

Implementation of science policy is achieved through responsible investment in science and technology. The budgeting process that provides for these investments is lengthy and complex, reflects many sometimes-competing interests, and is constrained by budgetary reality. Clearly, priorities reflecting current needs guide the process. A simplified view of the budget process is diagrammed in Figure 9.

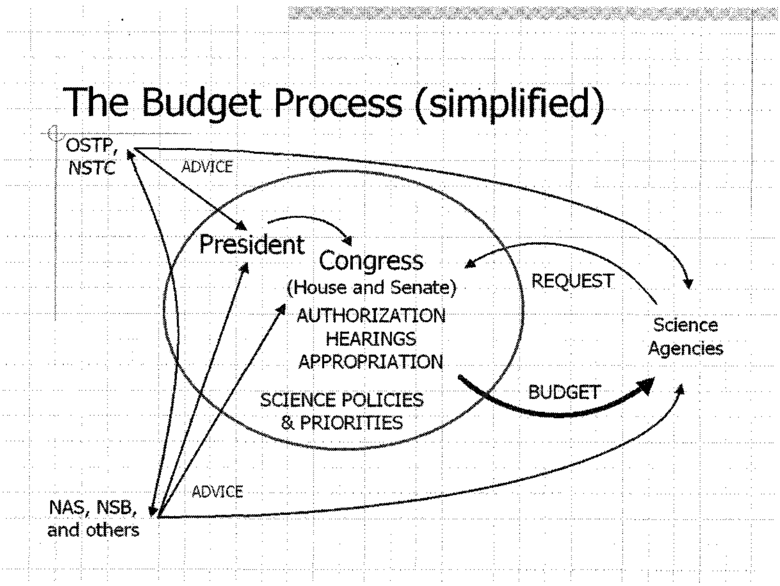


Figure 9. The budget process (simplified)

In Figure 9, the large oval indicates a "budget space" (defined by science policies and priorities, and constrained practically by budget size) within which the highly interactive budget deliberations and decisions occur. Advice from governmental (OSTP, PCAST, NSTC) and non-governmental (NAS, NSB and others) sources enters the process to guide the President and budget legislators in Congress. Authorization legislation by the Congress establishes limits on budget size and future budget growth for individual organizations and agencies. Science funding agencies submit budget requests based on authorizing legislation and other guidance. Within the budget request, organizational priorities are expressed; these organizational priorities are generally consistent with, and address, national priorities. Formal hearings in Congress provide an opportunity for legislators to examine the budget in detail, and for representatives from requesting agencies to explain and defend specific items in the request. Based on information in the draft budget and on the hearings, and in the context of national priorities, the President and Congress (both the Senate and the House of Representatives) negotiate a final budget appropriation that is passed in the Congress and signed by the President. The highly interactive nature of the process, although time consuming, results in a final budget that provides strategic government-wide S&T investments in science agencies.

VI. Funding Agency Perspective—National Science Foundation

Federal agencies, within the context of their individual missions, develop S&T funding priorities that address critical research fields and their enabling infrastructures, strengthen education, focus on long term activities that require federal backing to attain goals important to the nation, maximize efficiency and effectiveness through competitive peer review, and use collaborations within and among sectors when appropriate (http://www.ostp.gov/html/ombguidmemo.pdf). The criteria applied for assessing R&D investments are quality, relevance and performance (Figure 10).

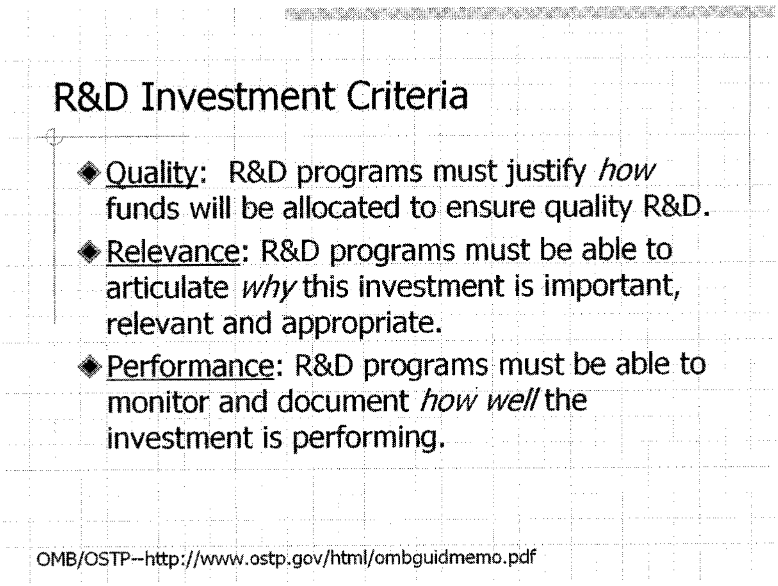


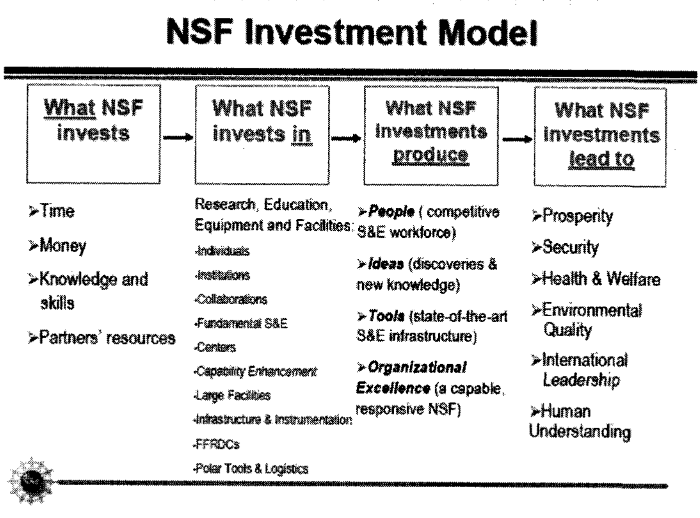
Figure 10. R&D investment criteria

As an example of science agency management of investments in S&T research, the policy and priority setting operations of the National Science Foundation can be examined. NSF supports science and engineering research and education across a broad array of scientific and engineering fields. NSF funding programs are open and accessible to the research community. Typically, in response to program announcements or solicitations, individual researchers or groups or organizations submit requests ("proposals") for funding support. Following careful review and evaluation, those proposed projects and activities judged to be the best with regard to scientific merit and to broader impact (on the advancement of knowledge in other fields and on training, for example) are selected to receive funding. Competition for funds is strong; in FY2003, the success rate for submitted proposals was 27%.

Strategic and performance planning. Within the Foundation, organizational policies and priorities (within the overall context of national priorities and the amount of appropriated funds) determine the budget distribution among fields and activities. Within the Foundation, guidance comes from the NSB and from the reports of external advisory committees of experts in relevant fields. For special purposes and funding initiatives, task forces and *ad hoc* committees may be convened to offer advice and recommendations. The investment priorities for NSF are contained with its five-year strategic plan and its one-year performance plan. These detailed documents chart the course for funding support for science and engineering research, including science, mathematics, engineering and technology education. Under the current plan, there are three foci that underlie investments in all areas of support; these are:

- ***People***: investments to build a world-class science and engineering workforce through education and training,
- ***Ideas***: investments to generate new knowledge across the frontiers of science and engineering through support of research activities, and
- ***Tools***: investments to get the job done efficiently and effectively through provision of major equipment and facilities.

These foci are part of the larger NSF investment model that links investments with outcomes (Figure 11; NSF 2003-2008 Strategic Plan).



NSF 2003-2008 Strategic Plan

Figure 11. NSF investment model

Although investments are made broadly across science and engineering disciplines, several specific priority areas are identified for their potentially important contribution to advancing knowledge and to addressing national priorities. In the FY2005 budget request, these organizational priorities are:

- Biocomplexity in the Environment
- Nanoscale Science and Engineering
- Mathematical Sciences
- Human and Social Dynamics
- Workforce for the 21st Century

There are, additionally, large "cross-cutting" initiatives in which NSF participates with other federal agency partners; these include:

- Networking and Information Technology R&D
- National Nanotechnology Initiative
- Climate Change Science
- Homeland Security and Antiterrorism R&D
- Molecular-level Understanding of Life Processes
- Education Research

The budget and planning documents detailing these foci, investment criteria and priorities are available on the Foundation's Performance Assessment Information Web site (http://www.nsf.gov/od/gpra/start.htm).

Outcome reporting. The Government Performance and Results Act (GPRA, enacted in 1993), provides for strategic planning and performance measurement in the federal government. The requirements for strategic planning are addresses by establishing policies and setting priorities as discussed above. Performance measurement is accomplished through outcome reporting to demonstrate the responsible investment of funds in S&T research and development. Using a variety of assessment measures, program management and achievements in discovery and innovation are documented. Information from performance reports is used to gauge the actual effectiveness of the investment portfolio and to guide future planning, including changes in priorities in accordance with needs and improvements in management and efficiency. Outcome reporting can be difficult over the short term since advances in basic knowledge and the new technologies and applications to which they lead, sometimes appear only after several years. Nevertheless, some objective measures of research productivity (numbers of published reports or patent applications from funded research projects, or changes in student achievement following implementation of an experimental science education program, for example) are possible. Annual performance reports from NSF are available for on-line viewing (http://www.nsf.gov/od/gpra/start.htm).

VII. Where to Find More Information

Analyses of trends in science and engineering R&D in the United States and globally are available on-line for the interested reader. The Web site of the NSF Division of Science Resources and Statistics (http://www.nsf.gov/sbe/srs/stats.htm) contains a wealth of information, including longitudinal data on R&D investments and some objective measures of research and development productivity. The resources listed in the next section are useful starting points for further study of U.S. Science policy.

Any opinions, findings and conclusions, or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation.

VIII. References and Resources

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Web Sites:

National Science Board (NSB)

http://www.nsf.gov/nsb

National Science Foundation (NSF)

http://www.nsf.gov

Office of Science and Technology Policy (OSTP)

http://www.ostp.gov

President's Council of Advisors on Science and Technology (PCAST)

http://www.ostp.gov/pcast/pcast.html

National Science and Technology Council (NSTC)

http://www.ostp.gov/nstc/html/nstc.html

The National Academies (National Academy of Sciences, National Academy of Engineering, Institute of Medicine and National Research Council)

http://www.nas.edu